Influence of nitrapyrin on N_2O losses from soil receiving fall-applied anhydrous ammonia

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ABSTRACT

Fertilizer application in crop production agriculture has been identified as a major source of the greenhouse gas nitrous oxide. Thus, management strategies that increase fertilizer N use efficiency will reduce N_2O emission. Anhydrous ammonia applied to cropland in the fall is recognized as a management practice that increases the risk of N loss from the rooting zone, however, this practice is still common in the U.S. Midwest Corn Belt. The nitrification inhibitor, nitrapyrin has been shown to decrease soil N losses during the fall and spring, and maintain fertilizer N availability to the crop. Additionally, nitrification inhibitors have shown promise in reducing soil N_2O emissions. However, there have been no studies evaluating the effectiveness of nitrapyrin to reduce annual N_2O emissions from land receiving fall-applied anhydrous ammonia. This study was conducted over 2 years to measure N_2O emissions from corn plots with fall-applied anhydrous ammonia with and without nitrapyrin. Based on soil NO_3 and NH_4 analyses, we observed that nitrapyrin delayed nitrification, and in 1 year, reduced late fall/early spring N_2O emission. However, annual N_2O emissions were not significantly reduced. Significantly higher corn grain yields were observed in the nitrapyrin treatment in both years.

Published by Elsevier B.V.

1. Introduction

Nitrous oxide is a major greenhouse gas (GHG) that contributes approximately 6% to the total radiative forcing of the earth's atmosphere (Intergovernmental Panel on Climate Change, 2006). It is estimated that in 2007 total GHG emissions in the U.S were 7125 Tg CO_2 Eq., and that the agriculture sector contributed approximately 413 Tg CO_2 Eq. to this total. Nitrous oxide from agricultural soil management is responsible for approximately 67% of the U.S. N_2O emissions (USEPA, 2009). Over the past 25 years agricultural impacts on soil emissions have been extensively studied, and it is generally acknowledged that N fertilizer management can have a major impact on soil N_2O emissions. Nitrogen fertilizer rate, timing, type and placement are deemed to be important factors influencing N_2O emissions (Eichner, 1990). Bouwman et al. (2002) analyzed 846 studies and concluded that N_2O emissions were generally higher from injected fertilizers as compared to surface broadcast fertilizers, and that N_2O emissions were lower for nitrate-based fertilizers than for anhydrous ammonia. Over a 140 d field study conducted by Breitenbeck and Bremner (1986) significantly higher N_2O emissions were observed in anhydrous ammonia treatments than in plots fertilized with aqueous

ammonia, urea, or calcium nitrate. The generality of these results has been questioned (Mosier, 1994; Smith et al., 1997) because the plots were fallow after fertilization in June. However, Venterea et al. (2005) showed significantly higher N_2O emissions in spring-applied anhydrous ammonia treatments as compared to urea–ammonium–nitrate (UAN) and broadcast urea treatments. During this 6-month study the treatments were planted to corn.

Fall-application of anhydrous ammonia is a common N management practice in the Midwest Corn Belt. However, because of the time lag between N application and corn planting the following year, there is a potential for N loss from the rooting zone. To reduce the risk of N loss it is recommended that fall-applied N occur after soil temperatures (10–15 cm) are below 10 °C (Keeney, 1982; Nelson and Hansen, 1968). Application of nitrification inhibitors is another recommended practice to preserve fall-applied N in the rooting zone by reducing nitrate leaching during periods when a crop is not present (Meisinger et al., 1980).

In addition to reducing fall and spring nitrate leaching losses, nitrification inhibitors have been reported to be effective in reducing N_2O emissions. Nitrapyrin is a compound that has been shown to effectively inhibit nitrification (Keeney, 1986). In short-term laboratory experiments, nitrapyrin was found to effectively reduce N_2O fluxes from soils amended with $(NH_4)_2SO_4$ or KNO_3 (Aulakh et al., 1984). Field experiments have shown similar results. Bronson et al. (1992) observed approximately 3-fold higher N_2O emissions in urea treatments than in urea + nitrapyrin treatments.

In these experiments the N fertilizer was surface broadcast in the spring, and N_2O emissions were measured over the 40 d following fertilization. Nitrapyrin was found to significantly reduce annual cumulative N_2O from a grassland fertilized with urea, but not with ammonium sulfate (McTaggart et al., 1997). Given the numerous possible combinations of fertilizer N forms, placements, and application times, these past studies do not cover the range of possibilities in evaluation of the effectiveness nitrapyrin in reducing N_2O emissions. We are aware of no studies evaluating the effect of nitrapyrin on cumulative annual N_2O emissions from fall-applied, injected anhydrous ammonia. Thus, the objective of this study was to determine the influence of nitrapyrin (N-Serve) on N_2O losses from soils receiving fall-applied anhydrous ammonia. Additionally, the influence of nitrapyrin on corn yield was evaluated.

2. Methods

2.1.1. Site description and soil characteristics

A field study was conducted at two sites an Iowa State University research farm located in Boone Co., Iowa (42.04°N, 93.71°W). At site 1 twelve field plots were established (15.25 m long by 7.6 m wide—10 corn rows wide). On November 14, 2005 anhydrous ammonia (90 kg N/ha) was applied to 6 plots and the other 6 plots received anhydrous ammonia (90 kg N/ha) with nitrapyrin (2-chloro-6-(trichloromethyl)pyridine) applied in N-Serve (Dow Agrosciences LLC, Indianapolis, IN). The nitrapyrin was applied at a rate of 0.38 L/ha (0.56 g active ingredient/ha). The anhydrous ammonia was applied with a knife injector in bands separated by a distance of 76 cm. On November 23, 2005 K_2O and diammonium phosphate were surface broadcast at rates of 134 kg K_2O/ha and 90 kg P_2O_5/ha. The additional N application in the diammonium phosphate was 35 kg NH_4-N/ha. The plots were planted to corn (Zea mays L. (Pioneer 34A16)) on May 5, 2006 at 82,990 seeds/ha. Corn was harvested on November 1, 2006. Grain from rows 2, 3, 4, 7, 8 and 9 of each plot were weighed for yield determinations. Grain moisture was determined and yields are expressed on a dry weight basis.

On November 21, 2006 12 plots (40 m by 3.8 m—5 corn rows wide) were established at a second site, and anhydrous ammonia was applied with a knife injector at a rate of 168 kg N/ha. At this time 6 of the plots received nitrapyrin at a rate of 0.38 L/ha (0.56 g active ingredient/ha) with the fertilizer N application; the other 6 plots received the same fertilizer rate with no nitrapyrin. Corn (DEKALB DKC-16) was planted on May 16, 2007 at a rate of 88,225 seeds/ha, and corn was harvested on October 22, 2007. Grain from the center 3 rows of each plot (rows 2, 3 and 4) was collected and weighed for yield determinations. Yields are expressed on a dry weight basis.

The previous-year crop at both sites was soybean (Glycine max [L.] Merr.). The tillage regime at both sites consisted of fall strip till prior to anhydrous ammonia application, and spring cultivation with a field cultivator the week prior to corn planting.

2.2. Soil sampling

The soils at both sites are mapped as a Canisteo silty clay loam soil (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls) (Andrews and Diderikson, 1981). Surface soil (0–15 cm) was sampled by collecting soil cores (3.35 cm diameter) within and between fertilizer bands. Three soil cores were collected in each location and bulked. In the laboratory samples were weighed and sieved (2 mm). Subsamples were collected for water content determination by oven drying at 105 °C, and 25 g field moist soil was extracted with 2 M KCl (100 mL) for nitrate and

ammonium analyses. The remaining soil was air dried and ground with a roller mill for organic C and N determination by dry combustion with a Carlo-Erba NA 1500 CHN elemental analyzer (Haakes Buchler Instruments, Paterson, NJ[1]) after removal of carbonates (Nelson and Sommers, 1996). pH was measured in 1:1 distilled water:soil slurries. Bulk density was computed from the soil sample weights (corrected for water content) and the known core volume. Soil texture analyses were performed by Midwest Laboratories, Inc. (Omaha, NE). Nitrate (+nitrite) and ammonium were determined by colorimetric analyses of 2 M KCl soil extracts (4:1 KCl to soil) on a Lachat autoanalyzer (Lachat Instruments, Loveland, CO) following the procedure described by Keeney and Nelson (1982). Physical and chemical properties of soil from the two sites are shown in Table 1.

2.3. Nitrous oxide flux measurements

Soil N_2O emissions were measured from November 2005 to December 2006 at site 1, and from November 2006 to December 2007 at site 2. Two PVC rings (30 cm diameter × 10 cm tall) were installed in each plot to a depth of approximately 6 cm. The rings were installed immediately after fall fertilization, and served as bases for flux chambers. In each plot one ring was installed directly over a fertilizer slot and the other ring was installed between fertilizer slots. Rings were left in place during the entire sampling period unless they were removed for planting. Flux measurements were performed by placing vented chambers (30 cm diameter × 10 cm tall) on the rings and collecting gas samples 0, 15, 30, and 45 min following chamber deployment (Parkin and Kaspar, 2006). At each site measurements were made once per week from April to September, twice per month in October and November, and once per month in December, January and February. Flux chambers were constructed from PVC and covered with reflective tape. At each time-point chamber headspace gas samples (11 mL) were collected with polypropylene syringes and immediately injected into evacuated glass vials (6 mL) fit with butyl rubber stoppers. Nitrous oxide concentrations in samples were determined with a Shimadzu gas chromatography (Model GC17A, Shimadzu, Columbia, MD[1]) equipped with a [63]Ni electron capture detector and a stainless steel column (0.3175 cm diameter × 74.54 cm long) with Porapak Q (80–100 mesh). Samples were introduced into the gas chromatograph using an autosampler described by Arnold et al. (2001). Nitrous oxide fluxes were computed from the change in N_2O concentration with time, after accounting for diffusion effects by applying the algorithm developed by Hutchinson and Mosier (1981). Based on our precision of N_2O measurement at ambient N_2O concentrations (approximately 5%), our estimated minimum detectable flux is 4.2 g N_2O-N ha^{-1} d^{-1}.

2.4. Ancillary field measurements

Daily precipitation totals and average air and soil temperatures were collected at a meteorological station 0.5 km west of the study area (Herzmann, 2004). Soil temperatures (5 cm) were measured at the time of gas sampling using a digital soil thermocouple temperature probe. Surface soil water content (0–6 cm) was measured using a ML2 soil moisture sensor (Delta-T, Cambridge, England[1]) at the times of N_2O flux measurements.

Table 1
Properties of soil samples collected at two sites (0–15 cm).

Site	Bulk density (Mg m^{-3})	pH	Organic N (g kg^{-1})	Organic C (g kg^{-1})	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})
Site 1	1.15 (0.05)	6.9 (0.25)	2.15 (0.19)	25.1 (2.0)	420 (33)	380 (35)	200 (18)
Site 2	1.14 (0.06)	7.7 (0.23)	2.69 (0.25)	32.9 (2.6)	300 (51)	410 (40)	290 (31)

Analyses were performed on 3 cores (0–15 cm) collected from each location and bulked.
Shown are means with associated standard deviations in parentheses.

2.5. Statistics

Comparisons between treatments on individual sampling dates and of cumulative N$_2$O emissions were performed using *F*-protected *t*-tests. Statistical tests were performed with SigmaStat software (SigmaStat Version 2.03).

3. Results

3.1. Site 1

Daily N$_2$O emissions were less than 10 g N$_2$O-N ha^{-1} d^{-1} during the fall of 2005 and winter-early spring of 2006 (from DOY 319, 2005 to DOY 50, 2006, Fig. 1). During this time average daily air temperatures were typically less than 0 °C, and few precipitation events occurred. Average daily air temperatures increased to 10 °C from February 19, 2006 (DOY 50) to April 4 (DOY 94) and N$_2$O emissions also increased, but remained below 20 g N$_2$O-N ha^{-1} d^{-1}. On March 6 (DOY 65) N$_2$O emissions were significantly higher ($P = 0.025$) in the control plots (10.8 g N$_2$O-N ha^{-1} d^{-1}) than in the nitrapyrin plots (3.1 g N$_2$O-N ha^{-1} d^{-1}). Nitrous oxide emissions were also significantly higher ($P < 0.031$) in the control plot on April 11 (DOY 101), and April 19 (DOY 109). From April 28 (DOY 118) to April 30 (DOY 120) the site received a total of 54 mm
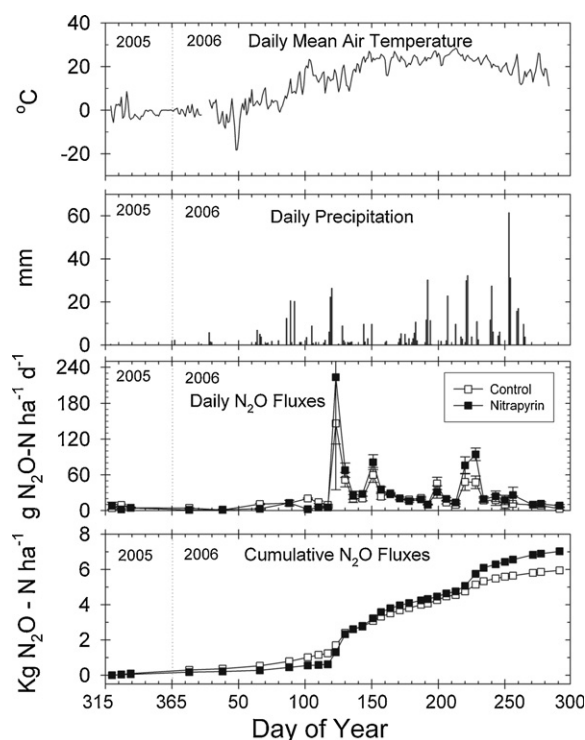
Fig. 1. Daily mean temperature, daily precipitation and nitrous oxide fluxes at site 1. Closed squares indicate N$_2$O emissions from plots with anhydrous ammonia + nitrapyrin. Open squares indicate N$_2$O emissions from plots with anhydrous ammonia with no nitrapyrin. Error bars associated with N$_2$O emissions are standard errors of 6 replicate plots.

of rain and on May 2 (DOY 122) a peak in N$_2$O emission was observed in both the nitrapyrin and control plots. Despite the apparent larger fluxes in the nitrapyrin plots, emissions during this peak event were not significantly different ($P = 0.587$) than, the control plots. Other smaller peaks of N$_2$O throughout the summer and fall of 2006, and on one of these sampling dates August 15 (DOY 227) emissions were significantly higher ($P < 0.029$) from the nitrapyrin plots than the control plots. Cumulative N$_2$O emissions were significantly higher in the control plots over the period of November 15, 2005 to April 26, 2006 as compared to the nitrapyrin plots (Fig. 1 and Table 2), but over the time period of April 26–October 17, 2006 (DOY 116 to DOY 290) cumulative fluxes from the two treatments were not significantly different. Over the entire sampling period, cumulative N$_2$O emission from the nitrapyrin treatment tended to be higher than the control (5.94 kg N$_2$O-N ha^{-1} vs. 7.03 kg N$_2$O-N ha^{-1}, Table 2); however, this apparent difference was not significant ($P = 0.324$).

The nitrapyrin appeared to be effective in limiting late fall/early spring nitrification activity. On April 19, 2006 (DOY 109) average soil nitrate concentration (0–15 cm) in the control treatment exceeded 50 g NO$_3$-N kg^{-1} soil (Fig. 2). This concentration was significantly higher ($P < 0.001$) than the average nitrate concentration in the nitrapyrin treatment (19.7 g NO$_3$-N kg^{-1}) on this date. On all other sampling dates nitrate concentrations of the two treatments were not significantly different. Ammonium concentrations exhibited a high degree of variability (CVs ranged from 30 to 213%). This sampling variability was likely the result of heterogeneous N fertilizer distribution due to the banded fertilizer application.

3.2. Site 2

The temporal variations in N$_2$O at site 2 showed a typical pattern of generally low fluxes punctuated by a few peak events (Fig. 3). During the late fall of 2006 to early spring of 2007 (DOY 315, 2006 to DOY 80, 2007) N$_2$O emissions were less than 10 g N$_2$O-N ha^{-1} d^{-1}. Four peak events occurred during the sampling season (DOY 79, DOY 89, DOY 117 and DOY 128). The elevated N$_2$O emissions (54.4 and 22.8 g N$_2$O-N ha^{-1} d^{-1} for the control and nitrapyrin treatments, respectively) observed on March 20, 2007 (DOY 79) may have resulted from a rapid soil warm up. Average daily surface soil temperature increased from 4.25 °C on March 19 (DOY 78) to 10.1 °C on March 21 (DOY 80) (data not shown). The site received 22.3 mm rain between March 21 and March 29 (DOY 80 to DOY 88), and N$_2$O emissions from the control and nitrapyrin plots averaged 35.7 and 29.3 g N$_2$O-N ha^{-1} d^{-1}, respectively. The two other peak emissions events on April 27 (DOY 117) and August 26 (DOY 238) also appeared to have occurred in response to rainfall. Significant differences ($P > 0.179$) were not observed on any sampling date at site 2. Similarly, there were no significant differences in annual cumulative N$_2$O emissions (Table 2).

Higher spring soil nitrate and ammonium concentrations were observed in the nitrapyrin treatment (Fig. 4). On April 6, 2007 (DOY 96) nitrate concentrations were not significantly different ($P = 0.63$), however, at several of the later sampling times (e.g.

Table 2
Effect of nitrapyrin on seasonal N_2O loss at two sites.

	Control (kg N_2O-N ha^{-1})	Nitrapyrin (kg N_2O-N ha^{-1})	P
Site 1			
November 15, 2005–April 26, 2006	1.24 (0.45)	0.62 (0.28)	0.017
April 26, 2006–October 17, 2006	4.71 (1.67)	6.40 (1.81)	0.121
November 15, 2005–October 17, 2006	5.94 (1.66)	7.03 (1.98)	0.324
Site 2			
November 27, 2006–April 27, 2007	2.72 (1.24)	2.50 (0.89)	0.717
April 27, 2006–October 11, 2007	3.09 (0.75)	2.77 (0.40)	0.373
November 27, 2006–October 11, 2007	5.81 (1.98)	5.26 (1.04)	0.559

Values in parentheses are standard deviations of 6 replicate plots of each treatment.
The column labeled 'P' indicates the probabilities associated with control and nitrapyrin t-test comparisons for each measurement period.

DOY 109, 136, 150, 163) significant differences were observed at a probability level of $P < 0.10$. The higher soil nitrate concentrations in the nitrapyrin treatment could have resulted from nitrification of the higher ammonium levels in this treatment. On April 6, 2007 (DOY 96) significantly ($P = 0.002$) higher ammonium levels were observed in the nitrapyrin treatment, indicating that the nitrapyrin prevented ammonium oxidization from the time of application. Throughout the rest of the spring, ammonium levels declined in both treatments, but were significantly ($P < 0.1$) higher in the nitrapyrin treatment on several sampling dates (DOY 109, 136, 163).

3.3. Corn yield

At both sites application of nitrapyrin with anhydrous ammonia injection impacted corn grain yields (Table 3). Grain yield in the control treatment (10.67 Mg grain ha^{-1}) and nitrapyrin treatment (11.77 Mg grain ha^{-1}) at site 1 were significantly different ($P = 0.045$). At site 2 grain yield from the nitrapyrin treatment was significantly higher than the control at a probability level of $P = 0.053$.

4. Discussion

Use of fall-applied N in the U.S. Midwest Corn Belt (Iowa, Minnesota, Illinois, Indiana, Ohio) is a common practice. According to the U.S. Department of Agriculture-Economic Research Service, in 2005 approximately 16.7 million hectares of land in this area was planted to corn (http://www.ers.usda.gov/Data/ARMS/CropOverview.htm). On average, 47.6% of this land (7.9 million ha) received fall-applied nitrogen (ranging from 181,800 ha in Ohio to 2,670,000 ha in Iowa). While the practice of N application in the fall is often advantageous to the farmer from a time and resource management perspective, it contains a greater risk of N loss from the rooting zone through leaching and denitrification (Keeney, 1982). The nitrification inhibitor, nitrapyrin has been shown to prevent these losses (Randall et al., 2003a; Randall and Vetsch, 2005a). However, persistence of nitrapyrin in soil (and hence, its efficacy in inhibiting nitrification) is strongly influenced by temperature and soil water content. Nitrapyrin hydrolysis was observed to increase at elevated soil water contents (Hendrickson and Keeney, 1978) and at higher soil temperatures (Hendrickson et
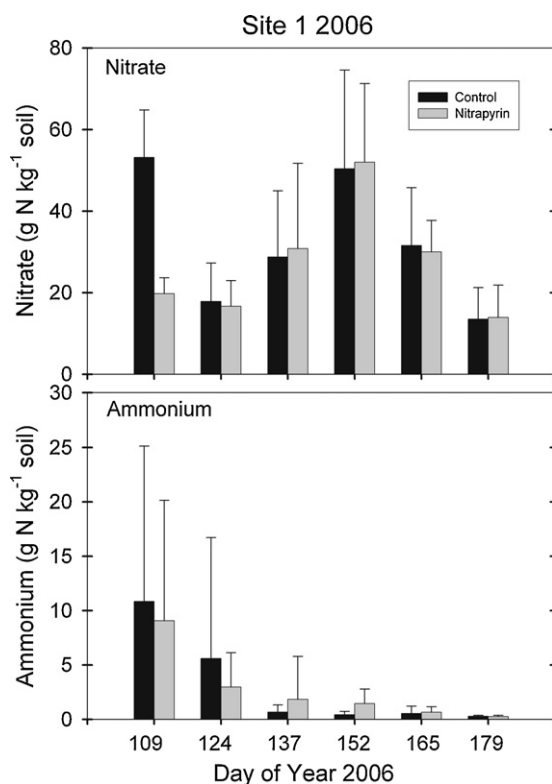
Fig. 2. Soil nitrate and ammonium concentrations at Site 1. Error bars are standard deviations of 6 replicate plots.
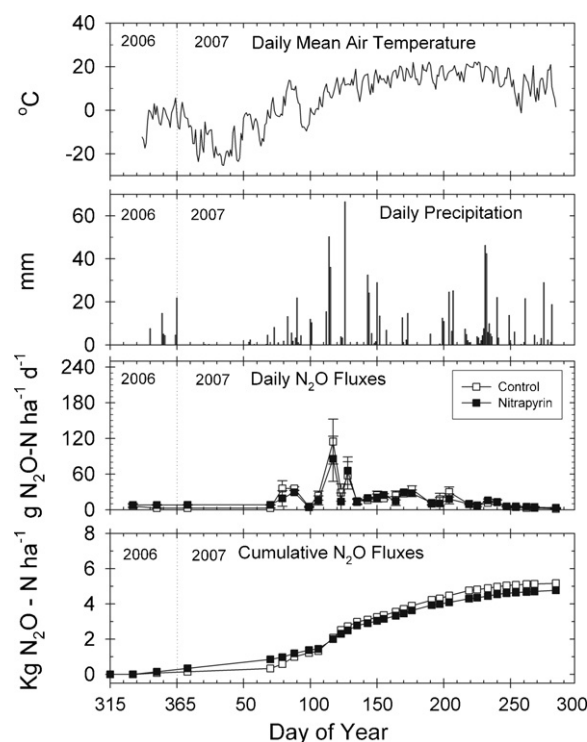
Fig. 3. Daily mean temperature, daily precipitation and nitrous oxide fluxes at site 2. Closed squares indicate N_2O emissions from plots with anhydrous ammonia + nitrapyrin, Open squares indicate N_2O emissions from plots with anhydrous ammonia with no nitrapyrin. Error bars associated with N_2O emissions are standard errors of 6 replicate plots.
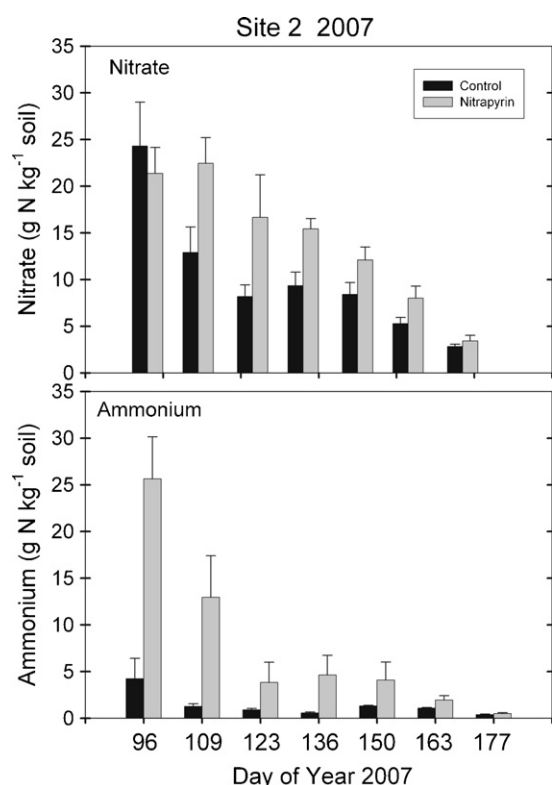
Fig. 4. Soil nitrate and ammonium concentrations at site 2. Error bars are standard deviations of 6 replicate plots.

al., 1978). Since both nitrapyrin degradation in soil and the nitrification process increase with increasing soil temperatures (Keeney and Bremner, 1967; Gomes and Loynachan, 1983), variability in weather conditions can contribute to the variability in inhibitor effectiveness. Because of the varied efficacy of nitrapyrin in controlling nitrification, Randall and Sawyer (2008) conducted an economic analysis of the use of nitrapyrin and concluded that its use is economically risky.

Generally it has been observed that anhydrous ammonia tends to increase N_2O emissions over the use of other types of fertilizer (Bouwman et al., 2002). Over a 140 d study with spring-applied anhydrous ammonia, aqueous ammonium, and urea, Breitenbeck and Bremner (1986) observed 3–6-fold higher N_2O emissions from the anhydrous ammonia treatments. However, in these experiments the plots were fallow. Venterea et al. (2005) observed that cumulative seasonal (April–November) N_2O emissions were 2–4-fold higher from corn plots that received anhydrous ammonia

treatments than plots that received UAN sprayed onto the soil surface or surface broadcast urea. In their study all N treatments were applied in the spring.

Use of nitrification inhibitors has been proposed as a strategy for mitigating soil N_2O emissions (Cole et al., 1997; Mosier et al., 1996; Smith et al., 1997; Snyder et al., 2009). Indeed, nitrapyrin has been shown to be effective in reducing N_2O emissions from spring-applied ammoniacal fertilizers (Aulakh et al., 1984; Bremner et al., 1981; Bronson et al., 1992; McTaggart et al., 1997). However, there have been few studies investigating nitrapyrin effects on N_2O production from anhydrous ammonia, and only one study where the anhydrous ammonia was fall-applied. In this later study (Magalhaes et al., 1984) observed cumulative N_2O emissions of 38 and 72 g N_2O-N ha^{-1} in anhydrous ammonia fertilized soils with and without nitrapyrin, respectively. However, this result was only observed in 1 of 3 soils investigated, and the monitoring periods ranged from 26 to 29 d following fertilizer application; not over an entire year. There is no available information on response of cumulative N_2O emissions to nitrapyrin use in conjunction with fall-applied anhydrous ammonia on an annual time step. Results of our study show that, in 1 year, nitrapyrin reduced N_2O emissions during the late fall and early spring by 0.62 kg N_2O-N ha^{-1}, but in both years cumulative annual N_2O emissions were not significantly reduced.

We observed greater corn yields in the nitrapyrin treatment, in both years. This result is similar to other studies that documented higher corn yields associated with the use of nitrapyrin with fall-applied anhydrous ammonia (Randall et al., 2003b; Randall and Vetsch, 2005b). The implication of greater yield with the use of nitrapyrin in conjunction with fall-applied anhydrous ammonia is that nitrapyrin increases fertilizer N use efficiency. In their 7-year study, Randall et al. (2003b) observed a higher apparent N recovery of fertilizer N with nitrapyrin as compared to the control (37% vs. 31%, respectively). In a 6-year study, Randall and Vetsch (2005b) calculated that apparent N recovery from fertilizer N averaged 47% without nitrapyrin, but was 56% with nitrapyrin. These authors concluded that weather induced variability, particularly in May and June was a primary determinant influencing fertilizer N recovery, and that nitrapyrin may be effective in reducing nitrate leaching losses. Randall et al. (2003a) observed a trend of higher NO_3-N leaching losses in corn plots fertilized anhydrous ammonia than with similarly fertilized plots with added nitrapyrin. It was concluded (Randall and Vetsch, 2005a) that use of nitrapyrin with fall-applied anhydrous ammonia could reduce nitrate leaching losses by 10% as compared to fall-applied anhydrous ammonia alone. If the use of nitrapyrin results in higher fertilizer N recovery and smaller NO_3-N leaching losses, then differences in indirect N_2O emissions may be important in assessment of N management effects on total N_2O emissions (both direct and indirect). Our study only

Table 3
Effect of nitrapyrin on corn grain yield.

	Control (Mg dry grain ha^{-1})	Nitrapyrin (Mg dry grain ha^{-1})	P
Site 1			
Harvested November 1, 2006	10.67 (0.76)	11.77 (0.71)	0.045
Site 2			
Harvested October 22, 2007	12.36 (0.28)	12.71 (0.27)	0.053

ANOVA					
Source of variation	DF	SS	MS	F	P
Year	1	9.464	9.464	33.862	<0.001
Treatment	1	2.843	2.843	10.173	0.005
Year × treatment	1	0.774	0.774	2.769	0.113
Residual	18	5.031	0.279		
Total	21	17.869	0.851		

Values in parentheses are standard deviations of 6 replicate plots of each treatment.
The column labeled 'P' indicates the probabilities associated with control and nitrapyrin t-test comparisons for each crop year.

measured direct soil N_2O emissions from soil, and no significant differences in annual emissions were observed. However, a complete assessment of the impact of N management on N_2O emissions to the atmosphere should include information on N leaching losses and on the conversion of this leached NO_3 to N_2O.

5. Conclusions

We observed significantly lower N_2O emissions from nitrapyrin-treated plots during November–April 2006, however, there was no significant effect of nitrapyrin on cumulative N_2O loss over entire year. There was no significant effect of nitrapyrin on soil N_2O emissions in the 2007 crop year. This indicates that there may be a potential for nitrapyrin reduction of N_2O, but the environmental conditions (primarily rainfall and temperature) must be conducive to allow this potential to be expressed. Nitrapyrin with fall-applied anhydrous ammonia significantly increased corn grain yield in both years. It should be noted that this study only evaluated direct N_2O emissions from soil. The influence of nitrapyrin on reductions of fertilizer N losses via nitrate leaching and, thus, its subsequent impact on indirect N_2O emissions remains to be investigated.

Acknowledgements

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